Title: Post-processing Data from Management Information System through a Water Poverty Index in East Africa

Article Type: Full Paper

Corresponding Author: Mr. Ricard Giné Garriga, MSc.

Corresponding Author's Institution: Universitat Politècnica de Catalunya

First Author: Ricard Giné Garriga, MSc; PhD Candidate

Order of Authors: Ricard Giné Garriga, MSc; PhD Candidate; Agustí Pérez Foguet, PhD

Manuscript Region of Origin: KENYA

(Initial page layout)

Post-processing Data from Management Information System through a Water Poverty Index in East Africa

R. Giné Garriga*[a], A. Pérez Foguet*[b]

* Research Group on Cooperation and Human Development (GRECDH), Civil Engineering School, Universitat Politècnica de Catalunya, Campus Nord, c/ Jordi Girona 1-3, Edif C2, 08034 Barcelona, Spain.
(E-mail[a]: *ricard.gine@upc.edu*)
(E-mail[b]: *agusti.perez@upc.edu*)

Abstract
This paper highlights the relevance of the use of the Water Poverty Index as an effective water management tool in resources allocation and prioritization processes. Nevertheless, three conceptual weaknesses exist in the current index, including redundancy among variables, the decision of assigning weights to them, and the aggregation method.

Based on a post process of readily available but sector relevant data, a revised method to construct the index has been developed through a case study in Kenya, at local scale. The paper discusses the results of this application. In particular, different approaches to exploit the index as a policy tool are presented, with the aim of enabling a more comprehensive understanding of the water sector constraints and challenges, and thus enhance related decision-making accordingly.

Keywords
Water poverty index; data management; Turkana district

INTRODUCTION

The issue of resources allocation is crucial in water management decisions. Policy makers are required to deal with an increasing and competing demand, though so often resources to meet those needs remain inadequate. If prioritization is made purely on the basis of where water is accessible, this is likely to be inefficient (Sullivan, 2002). In contrast, a key prerequisite to support effective policy making is to access consistent information through accurate monitoring backed up by rigorous interdisciplinary science, enabling decisions to be made on a much wider basis.

It is within this background that Sullivan (2002) developed the Water Poverty Index (WPI), as an attempt to advance the water-poverty interface and thus make water allocation more equitable. The index identifies regions facing severe water stress, by linking physical estimates of water availability and the socio-economic factors which impact on access and use of this resource. The WPI, though now well-established (Lawrence *et al.*, 2002; Sullivan *et al.*, 2003; Cullis and O'Regan, 2004; Komnenic, 2007), has been criticised on several grounds. In essence, it is noted (Molle and Mollinga, 2003; Shah and van Koppen, 2006; Komnenic, 2007; Jiménez *et al.*, 2008) that the index combines disparate (but correlated) pieces of information with arbitrary weights, which might result in questionable results.

This paper presents a case study developed using data provided by a comprehensive Management Information System (MIS) carried out by UNICEF for the Turkana District, in Kenya (UNICEF, 2006). It is believed that information in current database is not adequately integrated, hindering their use for policy and planning purposes. In a previous study (Giné and Pérez-Foguet, 2009a) it was shown that a post process of available data can produce easy-to-use water poverty maps (where water poverty takes its definition from the WPI), and provide a simple and powerful tool to both support water resource management and effectively tackle water poverty. However, and aimed at overcoming major criticism levelled at the WPI, a revised method (Giné and Pérez-Foguet, 2009b) to construct the index is employed in this paper. In addition, a cluster analysis is performed to present data in a user-friendly format, and thus allow policy planners to identify target groups and determine context-specific and more coherent strategies for the provision of this basic service.

THE WPI FRAMEWORK: A REVISED APPROACH

The purpose of a water poverty index is to produce a holistic policy tool in order to assess the degree to which water scarcity impacts on human populations. It combines measures of resource availability and access with measures of people's ability to access water. As Lawrence *et al.* (2003) state, people can be 'water poor' in the sense of not having sufficient water for their basic needs because it is not available. But people can also be 'water poor' because they are 'income poor'; and although water is available, they cannot afford to pay for it. In both cases, there is evidence that lack of adequate and sustained access to reliable water supplies leads to low levels of output and health (WHO/UNICEF, 2000; Sullivan, 2002; Molle and Molinga, 2003).

The development of such an index should enable decision makers to target crosscutting issues in an integrated way, by identifying and tracking the physical, economic and social drivers which link water and poverty (Sullivan, 2002). As a result, the core theoretical framework of the index encompasses water resources availability, people's ability to get and sustain access to water and to use this resource for productive purposes, and the environmental factors which impact on the ecology which water sustains. In brief, it has been designed to integrate into a single value five key issues relating to water resources. The 'resource' component (R) combines surface and groundwater availability, taking account of seasonal and inter-annual variability. 'Access to water' (A) includes not simply safe water for drinking and cooking, but water for irrigating crops or for non-agricultural use. The 'use' variable (U) focuses on the consumption of water in households as well as in different productive sectors, such as livestock and agriculture. 'Capacity' (C) comprises a set of indicators focusing on the human development of a region or area, and where possible aims to capture water institutional capacity. The 'environment' (E) component combines variables which are likely to impact on ecological integrity (such as biodiversity, environmental degradation, soil erosion, and water quality). The final value of the WPI for a particular location is given by the weighted summation function (Lawrence *et al.*, 2003):

$$WPI = \frac{w_r R + w_a A + w_c C + w_u U + w_e E}{w_r + w_a + w_c + w_u + w_e} \qquad (1)$$

where the weights applied to each of the five components (w_i) are constrained to be non-negative and sum to unity. As seen from the equation, there is built-in flexibility in the weighting assigned to the individual components, as well as in the choice of sub-components. Nevertheless, equal indicator weights are often preferred, since there is no evidence that it be otherwise. Likewise, use of an additive structure appears to make the index more transparent and acceptable to different stakeholders and decision-makers.

Recognizing the usefulness of this composite and its spread application, the authors of the original WPI and literature elsewhere have identified different concerns that arise when constructing the index. First weakness involves how the basic input data are used and the statistical properties of the index, criticizing it for conflating disparate (and often correlated) pieces of information (Molle and Mollinga, 2003; Jiménez *et al.*, 2008). Another major shortcoming is the weights assigned to the components of the WPI (which are undefined). Feitelson and Chenoweth (2002) argue that the weightings are subject to biases and individual judgments, though even when equal weighting for all components is in place, results are misleading. Similarly, Heidecke (2006) emphasizes the importance of transparent display of assigned weights to avoid misinterpretation. Finally, a more conceptual weakness is related to the aggregation method. In a linear aggregation, weights express trade-offs between indicators (Munda *et al.*, 1994; Nardo *et al.*, 2005). A shortcoming in one dimension thus can be offset by a surplus in another. In case there is a need to assure that weights remain a measure of importance or if different goals are equally legitimate, then the linear aggregation is not suitable and a non-compensatory logic might be necessary.

With the aim of overcoming previous criticism, a revised method to calculate the index was developed by Giné and Pérez-Foguet (2009b). Basically, it involved three key steps (Table 1): (1) selection and combination of key variables into their corresponding subindices, using an equal and dimensionless numeric scale; (2) determination of weights for each subindices and their aggregation to yield an overall index; and (3) validation of the composite using a sensitivity analysis.

Table 1. Basic steps in index design. *Source*: Giné and Pérez-Foguet, 2009b

1st: Selection of indicators	a. Compilation and validation of available data
	b. Definition and first proposal of indicators
	c. Classification of indicators, based on conceptual framework.
	d. Preliminary statistical analysis of proposed indicators
	e. Selection of indicators at subindex level
2nd: Construction of the index	a. Assignment of weights for subindices
	b. Aggregation of subindices
3rd: Validation of the index	a. Sensitivity analysis

Taking this methodological framework as a starting point, a number of combinations to create the WPI were considered (Giné and Pérez-Foguet, 2009b), and each approach was judged based on different criteria (Swamee and Tyagi 2000; Sullivan et al. 2003; Nardo et al. 2005; Singh et al. 2008): the method should (i) minimize overestimation (ambiguity) and underestimation (eclipsing); it should be (ii) simple and straightforward; (iii) sensitive to the changes in an individual variable throughout its range; and (iv) transparent so that the index can be readily disaggregated into the separate components with no information lost.

In the end, Giné and Pérez-Foguet (2009b) concluded that the weighted multiplicative function is the most appropriate aggregation function for estimation of water poverty. Numerically, it can be formulated as:

$$\mathrm{WPI} = \prod_{i=1}^{5} X_i^{w_i} \qquad (2)$$

where WPI is the value of the index for a particular location, X_i refers to component i (R, A,C, U, E) of the WPI structure for that location, and w_i is the weight applied to that component. The weights w_i indicate the relative importance of X_i, and they sum to one and are non-negative.

DEVELOPING A WATER POVERTY INDEX FOR THE TURKANA DISTRICT

This section focuses on applying this composite index methodology at local scale at a particular context (Turkana District, Kenya). The index is assessed on the basis of abovementioned procedure.

Case Study

Turkana District is located in Rift Valley Province, and borders on Uganda to the west, Sudan to the north west, and Ethiopia to the north east (see Fig. 1). Administratively, it is made up of 17 divisions, 58 locations and 158 sub-locations. The total population is estimated at 450.860, according to 1999 National Census (Fig. 2).

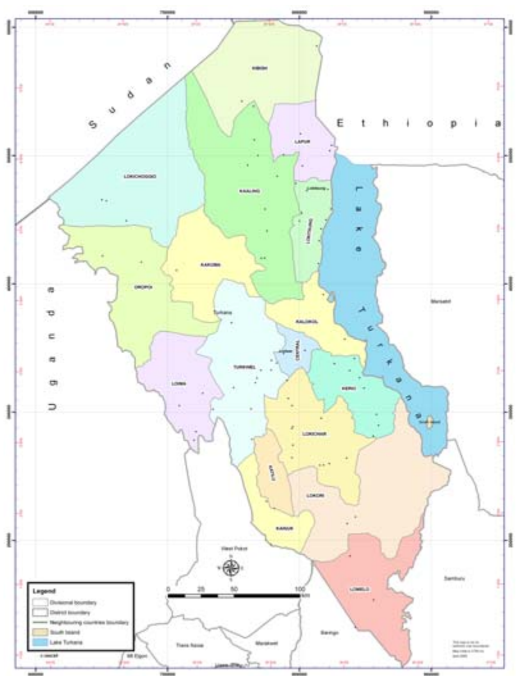


Figure 1. Administrative Boundaries of Turkana District. *Source*: UNICEF (2006)

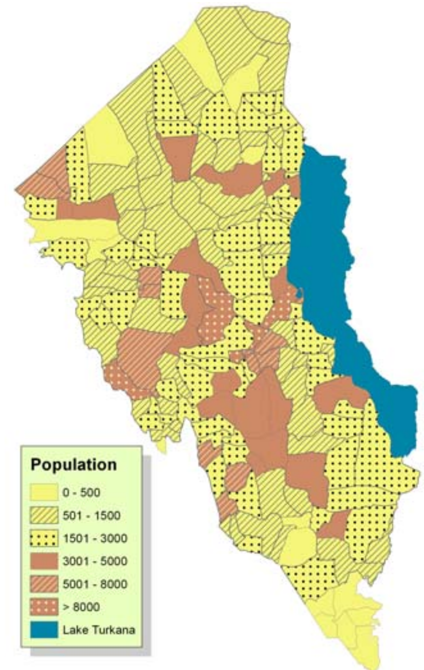


Figure 2. Population at sublocation level. *Source*: National Census (1999)

The District covers 70.720 km^2 of some of the most arid parts of Kenya, and is characterised by severe and recurrent droughts. Main factors associated with the water resources are:

- Rainfall amounts range from 120 to 430 mm (ALRMP, 2005). The occurrence of rainfall is highly erratic and unreliable, although the probability of rainfall is the highest during the long rain season between April and August.
- The main tributary of Lake Turkana is the River Omo, which enters the lake from Ethiopia and contributes more than 90% of the total water influx. Other rivers are seasonal (e.g. Kerio and Turkwel). The lake has no outlet, and water is lost mainly by evaporation. Therefore the water level is sensitive to climatic variations. Moreover, the area is exposed to strong winds which, together with high temperatures (daily average of 24-38 ºC), lead to high evaporation (Odada *et al*., 2003; ALRMP, 2005).
- The district has 4 main seasonal rivers (Turkwel, Kerio, Suguta and Tarach). This resource is mainly exploited via gravity (basin irrigation) and direct access for domestic and livestock water supply (UNICEF, 2006). Turkwel River was dammed in 1991 for hydroelectric power generation at Turkwel Gorge, and this has probably significantly impeded the flow of freshwater in the Turkwel River. Nevertheless, very little hydrogeological data is available and to determine the environmental effects of the dam construction remains elusive.
- Most of the population rely on river and shallow water wells for water, especially the shallow groundwater aquifer associated with dry riverbeds. However, main factor which diminishes its potential is poor water quality, rather than total absence (UNICEF, 2006). Ephemeral rivers also provide significant water sources mainly via shallow wells, being seasonal rivers the most abundant source of water in the district.

- Proper sanitation facilities are basically non-existent, particularly in the rural areas (Odada *et al*., 2003; UNICEF, 2006).
- Food security is inextricably linked to the freshwater resources. With the very low rainfall in the region, an increasing number of people are shifting from pastoralism to agro-pastoralism and thus becoming more vulnerable (Odada *et al*., 2003). Furthermore, freshwater shortage is likely to become more acute as water demand from the rivers to adjacent farms increases, and will be acutely accentuated during periods of drought. The higher populations close to the riverbanks are also likely to pollute water resources to significant levels, thus rendering the freshwater shortage more severe because of its reduced quality (Odada *et al.*, 2003).
- Health impacts will increase due to lack of sufficient and potable water supplies, and to inadequate sanitation infrastructure (Odada *et al*., 2003).

Method

Against this background, and in order to assist policy makers to tackle major water challenges at Turkana, an evaluation of the situation was carried out on the basis of the Water Poverty Index. To this end, the previous step-by-step method was employed (Table 1). A brief description follows (Giné and Pérez-Foguet, 2009b).

Data used (*step 1a*) was obtained from the 'Water, Schools and Health Management Information System (MIS) for Turkana District', which was developed by the Government of Kenya in cooperation with UNICEF as a comprehensive record of all water resources available in the district. Relevant data for each source (644 water sources) were obtained and entered into a Geographical Information System (GIS). In parallel, information related to rural water supply and sanitation (RWSS) service level was captured through a questionnaire administered at a waterpoint (488 questionnaires), addressing the level of service of all those that access the source.

Based on these two different information sources, a number of indicators were identified (*step 1b*) and classified (*step 1c*) according to the WPI framework (Table 2). To each parameter a score between 0 and 1 was assigned, where 1 represented best performance. Next step was aimed at deciding if the set of proposed indicators was adequate to assess each of five components of the index, in terms of redundancy and comprehensiveness. To this end, a preliminary assessment of the dataset was performed to explore whether the identified indicators were statistically well-balanced. A Principal Component Analysis (PCA) was applied (*step 1d*) with the objective of combining the initial battery of 25 indicators into composite variables which explained the maximum possible proportion of the total variance of the set. This approach showed that 12 factors accounted for 81.1% of the overall variability (Giné and Pérez-Foguet, 2009b), and that most of these principal components mixed indicators belonging to different WPI subindices. Thus, in this case, PCA did not justify WPI framework, although it neither offered a better alternative. The adequacy of the original structure was then confirmed in terms of transparency and relevance for the purpose of policy making.

After having undertaken a general preliminary evaluation, this process was repeated at subindex level (*step 1e*). PCA proved to be helpful to reduce the initial set of 25 "correlated" indicators into a group of fewer, 17 uncorrelated components (Table 2). Based on statistics obtained from these five independent analyses (R, A, C, U, E), subindices were described as the average of raw indicators that loaded most heavily on each principal component, thus removing from the dataset all correlated measures (i.e. 8 indicators). However, and since some variables were more difficult to assess than others, in cases where two or more indicators loaded roughly the same, we selected the most easily available one. On the basis of this criterion, in the Resources component the variable "Seasonal variability of water resources" was preferred to "Supply reliability"; in Capacity, "Legal registration of water entities" was included instead of "Funds audit"; and to assess the Access variable, "% of people who access improved waterpoints" appeared to be more straightforward than "Distance to water source".

Table 2. Structure of the index and variables used

WPI Component	**No. of Indicators** [a]	**Indicators** [b]
Resources	3 (1)	▪ Water Quantity Sufficiency; *Reliability of supply (% time not operational)*; Seasonal variability of water resources (months per year with water)
Access	6 (2)	▪ Access to improved waterpoints; Access to improved sanitation; *One way distance to water source*; *Waiting time (minutes)*; Cost of water; Operational status of water source
Capacity	6 (3)	▪ Management system; Ownership over water source; Water Association registered (Legal registration; *Records kept*; *Financial control*; *Funds audited*)
Use	5 (1)	▪ Domestic water consumption rate; Conflict over water sources (Human – Human); *Conflict over water sources (Human – Livestock)*; Use of local water treatment (boil water); Livestock water use
Environment	5 (1)	▪ Qualitative assessment of water quality; Protection of water sources; *Number of pollution sources around water sources*; Number of environmental impacts around water sources; Conflict over water sources (Human – Wildlife)

Note: (a) In brackets, number of indicators removed from each subindex based on correlation criterion; (b) In italics, indicators removed and not considered in this study.

With regard to the index construction, two different weighting systems were applied, and two aggregation forms were used to combine the five components of the index. The weights were calculated based on expert opinion (equal weights) and the statistical structure of the data set (*step 2a*); though it can be shown in Table 3 that there were no significant changes, and that final values of the index at sublocation level remained fairly the same. The aggregation functions considered were the additive and the multiplicative form (*step 2b*). Additionally, a simple sensitivity analysis was conducted to test robustness of the composite (*step 3a*).

The index was finally assessed at sublocation scale applying the weighted multiplicative function. The resulting WPI values fell in the range 0 to 1, where the highest value 1 denoted best situation (i.e. lowest level of water poverty), while 0 was the worst.

RESULTS AND DISCUSSION

This section attempts to analyse the concept of water poverty at the Turkana District through a comprehensive evaluation of achieved results. The usefulness and relevance of an integrated indicator approach for water policy making is highlighted; with a special focus on suggesting different alternatives which are aimed at exploiting the index as an efficient tool to support water management and resources allocation.

Table 3. Weights and weighting systems.

Subindex	No Weights	PCA
Resources	0,2	0,221
Access	0,2	0,245
Capacity	0,2	0,216
Use	0,2	0,177
Environment	0,2	0,141

There is little doubt that the way the composite index is disseminated is of primary importance, as this might influence its interpretation. The aim should be to provide clear messages and to communicate a picture to decision-makers quickly and accurately. In this study, a water poverty map has been developed (Figure 3) to show at a glance the level of water poverty. Mapping involves the presentation of certain information in a spatial context, and this enables policy planners to identify the communities in which to focus their efforts for maximum impact (Henninger, 1998).

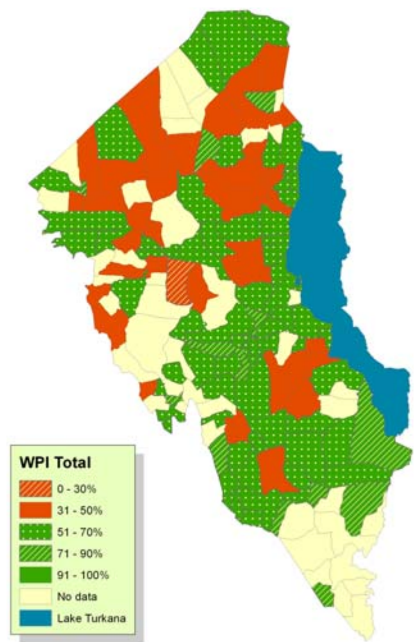


Figure 3. The Water Poverty Index, at sublocation level

In the end, a single number represents the water situation at each sublocation. In case this value is used as a performance indicator, the index is able to identify strengths and weaknesses in the water sector at a particular location, as well as to discriminate between different locations (Sullivan and Meigh, 2007). A straight comparison can be made in this regard when any location is compared for example to the leader, the laggard or the average performance. At the same time, if the WPI is updated at reasonable intervals, it could also be used to monitor progress.

In those cases where water management decisions are more focused on the issue of prioritization, a crucial factor is to determine who is the neediest. Then, final WPI values might serve as the basis to rank all locations and denote different priority, where the "lowest" priority is assigned to the least water poor location (i.e. the highest WPI value).

Back to the details

The index provides a starting point for analysis. However, an accurate focus on the five subindices might help to identify the source of the problem in particular places and direct attention to those water sector needs that require special policy attention. Therefore, the underlying complexities of the index need not be lost, and this is acknowledged by the authors (Lawrence *et al.*, 2002; Sullivan, 2002) who note that "the information is in the components rather than in the final single number".

For example, and in accordance with Figure 4, aspects requiring urgent intervention are those related to the "Access" and "Use" components. These two variables present an average value of 0.519 and 0.398 respectively, while three remaining subindices score considerably higher; i.e. Capacity (0.561), Environment (0.571), and Resources (0.698). Equally important, it can also be noted from the graph that poor correlation exists between five components and the final index (low regression coefficients). A revision of the correlation matrix (not shown here) confirms that variables are not redundant within them.

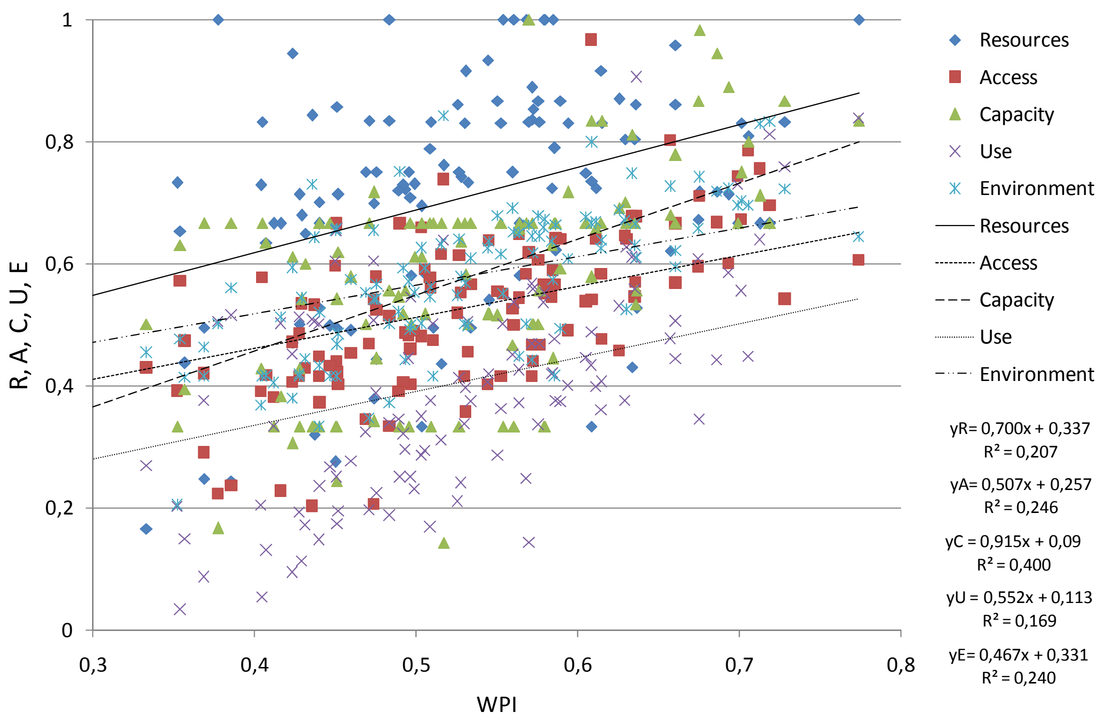


Figure 4. Water Poverty Index ($WPI_{2,W,G}$) and its five components.

Similar but complementary conclusions might be achieved by showing the values of all five components in a visually clear way, so a set of water poverty maps are developed at this level (Fig. 5). In this respect, and based on the "Resources" map, it can be seen that high values occur where surface water is available (in areas located near main rivers). In contrast, achieved results fail to reflect the fact that the district is classified as arid. It should be noted in this regard that no more than two indicators were used to define this variable, thus not only an accurate analysis of available data might be needed, but also better access to additional information sources, in order to complete a more precise picture of the situation . From the "Access" map, and contrary to what might be expected, it is observed that adequate density of water sources (defined as number of waterpoints per 1,000 beneficiaries) is not sufficient to ensure high scores of this variable. As a result, it is evident that indicators such as "cost of water" or "access to sanitation" also play a key role. According to the "Capacity" map, one might conclude that institutional framework to support communities to manage water facilities is far from being adequate. In fact, few water entities are legally registered, and if registered, they are not able to assume their commitment (in terms of revenue collection, financial control, keeping records ...). It can also be seen that this variable slightly improves in those sublocations where main towns or trading centres are located. Domestic water consumption is generally poor, and this is visualized in the "Use" map. Based on available data, more than 50% of population consumes less than 20 l.p.d. (minimum established by WHO) in 83 out of 99 sublocations. Finally, the "Environment" map shows that apparently water quality does not appear to be a major problem, though it should be highlighted that information was based on qualitative questionnaires and not on biochemical analysis.

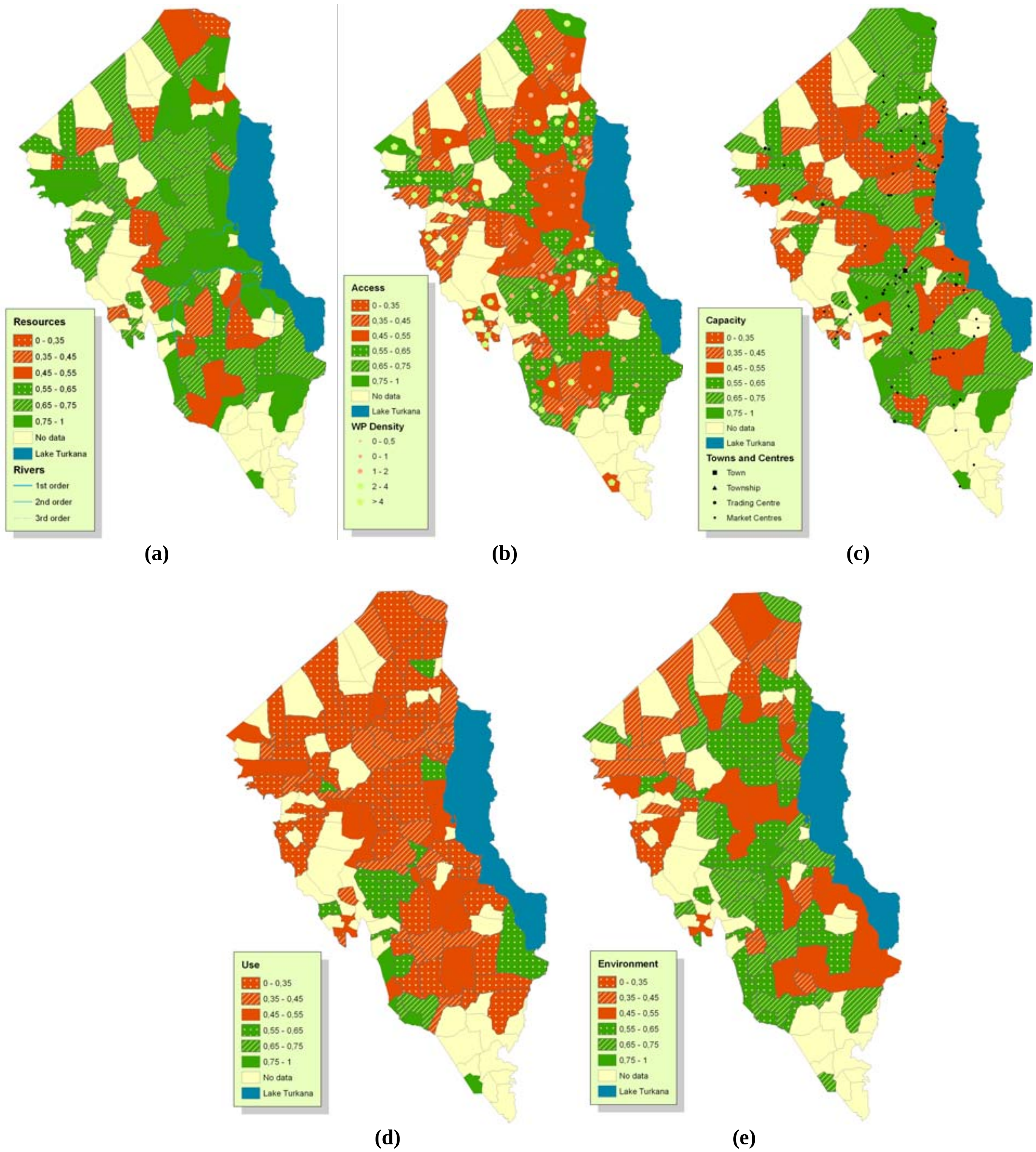


Figure 5. Five components of the Water Poverty Index: (a) Resources; (b) Access; (c) Capacity; (d) Use; (e) Environment.

Clusters of variables

In addition to previous analysis, cluster techniques are employed to define "comparable" sublocations and classify them into manageable sets, by exploiting their similarity on different indicators and variables. We use the k-means clustering method, which divides the sample in k clusters of greatest possible distinction (in this case, 5 clusters). The algorithm computes the similarity between sublocations in the dataset, with the aim of (i) minimise the variance of elements within the clusters, and (ii) maximise the variance of the elements outside the clusters (Nardo *et al.* 2005).

A spider diagram is displayed in Figure 6 to summarize the differences in the means between clusters, which are presented in Table 4. To understand particularities of these five groups, which are geographically depicted in the map (Fig. 7), allows policy planners to identify target groups and determine specific and more coherent strategies, which in terms of poverty reduction and allocation of resources is more efficient and cost-effective than to launch an equally expensive universal distribution program (Cullis and O'Regan 2004).

Table 4. Final cluster centres.

	1st Cluster	2nd Cluster	3rd Cluster	4th Cluster	5th Cluster
No. Sublocations	33	37	14	21	12
Population	84.617	79.299	34.568	126.481	37.887
WPI	0,578	0,453	0,428	0,663	0,373
Resources	0,857	0,711	0,347	0,689	0,647
Access	0,531	0,460	0,523	0,673	0,392
Capacity	0,546	0,565	0,527	0,775	0,256
Use	0,440	0,223	0,419	0,555	0,528
Environment	0,618	0,463	0,559	0,690	0,587

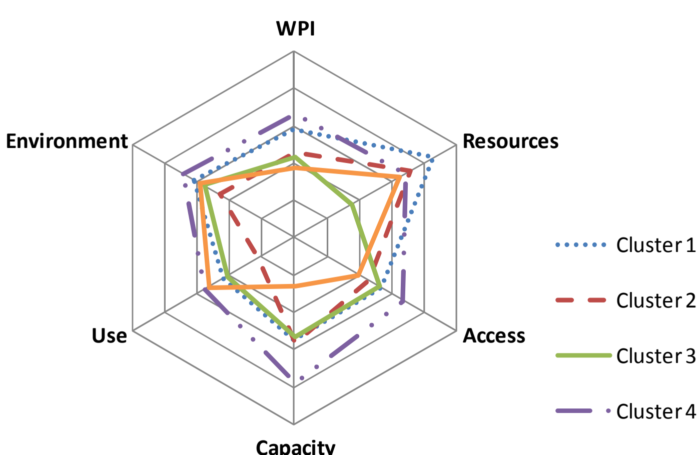


Figure 6. Diagram of WPI components for five cluster classes

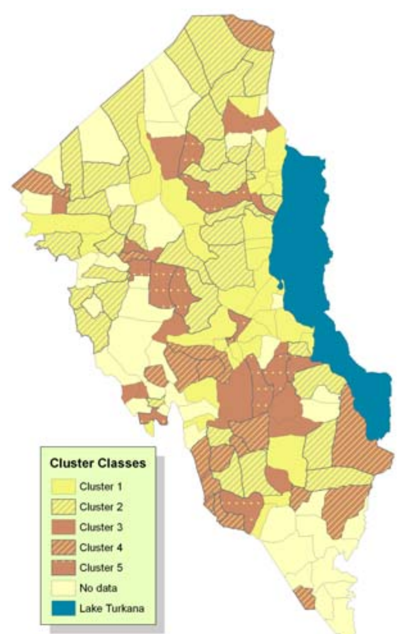


Figure 7. Map of Cluster Classes

It is shown for example that first cluster (which includes 33 sublocations, 84.617 people) scores best in "Resources", and achieves good marks for the other four components. The level of water poverty is thus low (Fig. 8a).

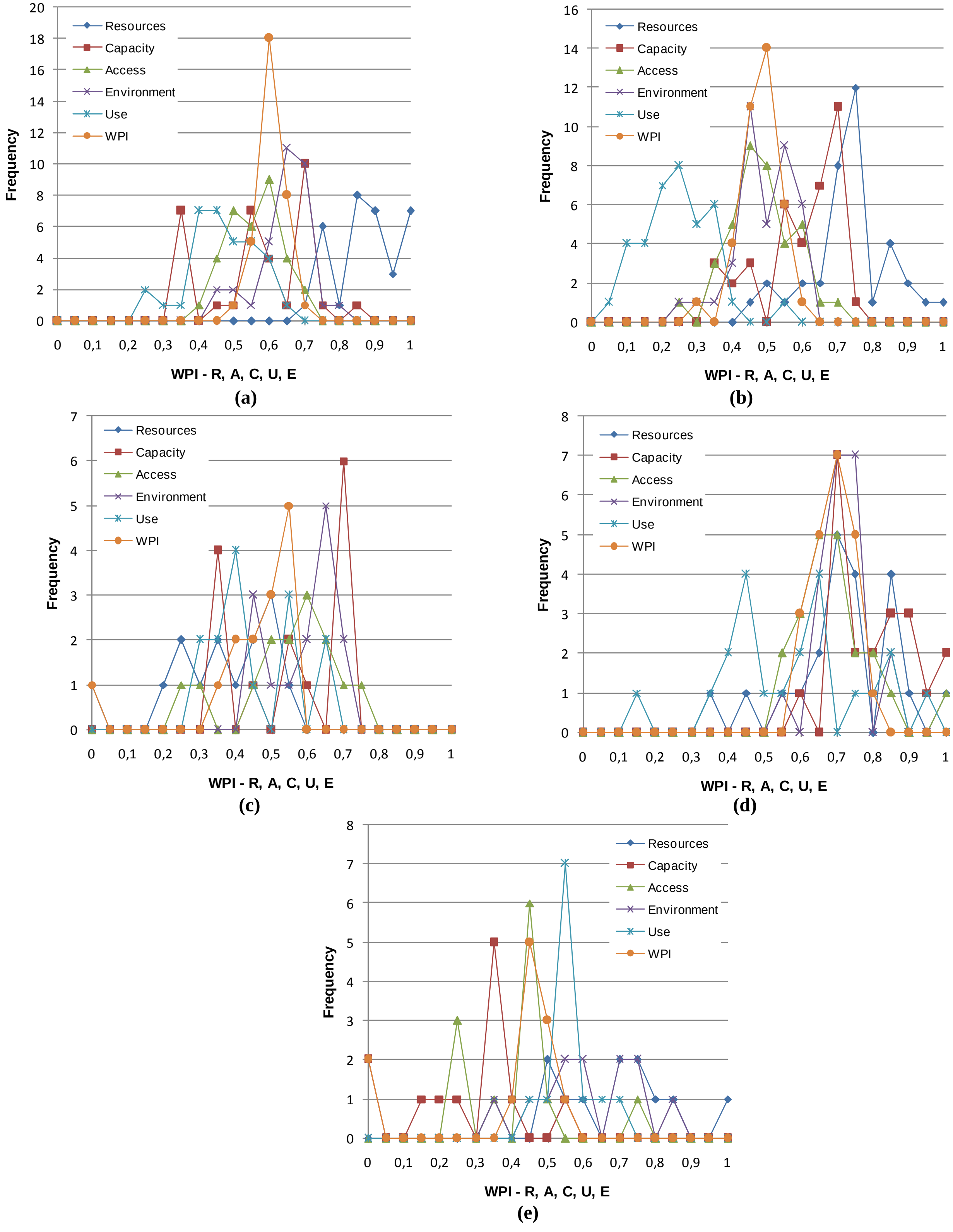


Figure 8. Histograms of Clusters. (a) Cluster 1; (b) Cluster 2; (c) Cluster 3; (d) Cluster 4; (e) Cluster 5

Cluster 2 corresponds to sublocations (37; 72.299 people) in which usage of water is inadequate, access to basic services remains low, and water sources are not properly protected from potential pollutant sources. Sanitation campaigns should thus be promoted to improve hygienic practices and to change behaviours, mainly aiming to raise awareness among the population of the importance to increase domestic water consumption. At the same time, water sources need to be protected to prevent water from being contaminated. Then, programs to construct new infrastructure should be launched to improve coverage (Fig. 8b).

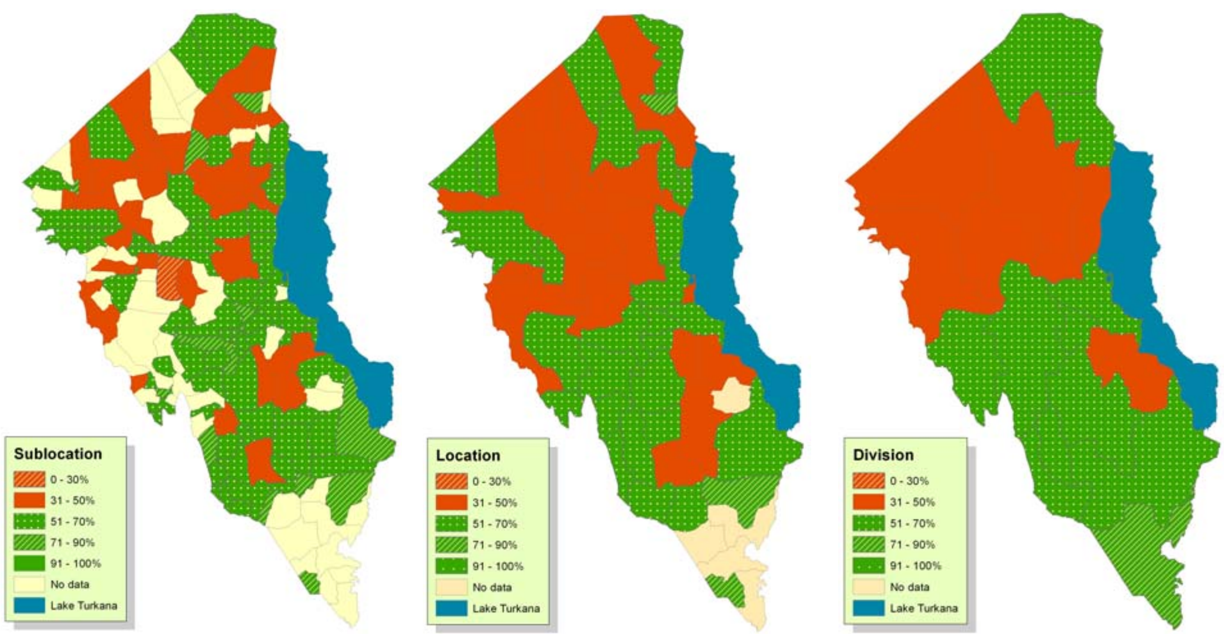
Sublocations (14; 34.568 people) included in Cluster 3 are characterized by facing acute water scarcity, though they lack capacities to manage water facilities, water use is poor and environmental impact on resources is considerable. Consequently, the level of water poverty is remarkable. First intervention should be directed to increase water reservoir availability. In parallel, capacity building of water entities need to be ensured. And equal to Cluster 2, hygiene promotion should be fostered, while awareness of the importance to protect water sources increased in the communities (Fig. 8c).

Cluster 4 (21 sublocations; 126.481 people) performs notably better, being the least water poor. Only the “use” component needs to be improved, since water consumption remains inadequate, though scoring the highest (Fig. 8d).

Finally, cluster 5 (12 sublocations; 37.887 people) score the lowest WPI values and thus represent the highest degree of water poverty. This group scores badly with respect to “Capacity” and “Access”. The direction to be adopted in sublocations included in this group should be that all water sector actors at local level conduct capacity building through appropriate training, so as to enable water entities to manage the schemes. Additionally, access to water and sanitation needs to be improved by increasing coverage (Fig. 8e).

Analysis at different administrative scales

In the last stage of the analysis, a set of water poverty maps have been developed at different administrative scales (Figure 9), by scaling available data from sublocation up to location and division levels.



(a) **(b)** **(c)**

Figure 9. WPI at (a) Sublocation scale; (b) Location scale; (c) Division scale

Certainly, the extent to which indices will accurately assess impact of development policies will depend on the scales at which they are applied. For example, an index at the regional level may say nothing about local variations; and improvements in access and availability to water at household level might be obscured by indices which operate at inappropriate scales.

In this respect, it can be seen from the maps that when the data is collected at the division scale, one large area is identified as the most water poor area, while if finer resolution data is used (i.e. at sublocation scale), a much clearer picture emerges of the location of the most water poor areas. Therefore, sublocations with low degree of water poverty appear as water poor at other administrative scales, and vice versa.

Similarly, the problem of missing data is highlighted. Due to inaccessibility and insecurity in parts of the district some water sources were not audited, which resulted in various sublocations being not covered. In this respect, percentage of population excluded of analysis was roughly 20%, though according to Figure 2, the majority of excluded sublocations were low densely populated areas. In this study, if data was missing no additional field work was planned. Therefore, in scaling up processes, the average of data of adjacent sublocations was considered.

CONCLUSIONS

The aim of this paper was to underline the usefulness of the Water Poverty Index as a policy tool to assist water resources management and effectively tackle water poverty. Its major advantage is that presented in a user-friendly format (such as poverty maps), it enables more comprehensive understanding of the water sector constraints and challenges, and enhance decision-making processes. Key findings follow:

- The water poverty index has been advanced from its original application, and a revised method is applied. Instead of an arithmetic mean of sub-components, a weighted multiplicative function appears to be more appropriate for estimation of water poverty.

- The usefulness of the WPI may not lie in its final values, but rather in its components themselves; which provide a rapid diagnosis for understanding the links between poverty, resource accessibility and institutional capacity. By showing the values of all five components in a visually clear way, it directs attention to those water sector needs that require urgent policy attention. Therefore, a focus on the variables and indicators rather than the final composite is recommended.

- A cluster analysis allows classifying all sublocations into manageable sets, based on their similarity on all indicators and variables. Understanding particularities of each group allows policy planners to identify target groups and determine specific and more coherent strategies, which in terms of poverty reduction and allocation of resources is more efficient and cost-effective.

- Identifying the water poor through related maps compares favourably with other methods currently used (reports, tables, graphs...). However, maps should be developed at a suitable scale to identify the regions in which sector policies and development will be most effective. In this respect, this study demonstrates the importance of using the finest resolution possible to produce the most accurate results.

ACKNOWLEDGEMENTS

The authors would like to extend thanks to UNICEF (Eastern and Southern Africa Regional Office and Kenya Country Office) and to Rural Focus Ltd. Consultancy, who has contributed and provided support for the assessment in various ways. Financial support from the Agència Catalana de Cooperació al Desenvolupament (Generalitat de Catalunya, Spanish government) and the Centre de Cooperació per al Desenvolupament (Universitat Politècnica de Catalunya) are gratefully acknowledged.

REFERENCES

- ALRMP (2005). *Arid and Semi Arid Lands. Turkana District Vision and Strategy: 2005-2015*. The Arid Lands Resource Management Project (ALRMP), Republic of Kenya, Nairobi.

- Cullis, J. and O'Regan, D. (2004). Targeting the water-poor through water poverty mapping. *Water Policy*, **6**, 397-411.

- Feitelson, E. and Chenoweth, J. (2002). Water Poverty: towards a meaningful indicator. *Water Policy*, **4**, 263-281.

- Giné, R. and Pérez-Foguet, A. (2009a). Enhancing sector data management to target the water poor. *Proceedings of the 34th WEDC Int. Conf.*, Addis Ababa, Ethiopia, May 2009.

- Giné, R. and Pérez-Foguet, A. (2009b). Improved method to calculate a Water Poverty Index at local scale. *Submitted to a scientific journal*.

- Heidecke, C. (2006). *Development and Evaluation of a Regional Water Poverty Index for Benin*. EPT Discussion Paper No. 145, International Food Policy Research Institute, Washington, DC.

- Henninger, N. (1998). *Mapping and Geographic Analysis of Human Welfare and Poverty: Review and Assessment*. World Resources Institute, Washington DC

- Jiménez, A., Molinero, J. and Pérez-Foguet, A. (2008) Monitoring Water Poverty: A vision from development practitioners. In: *Water Ethics*. 3rd Botín Foundation Water Workshop, June 2007. Taylor and Francis Group.

- Komnenic, V., Ahlers, R. and van der Zaag, P. (2008). Assessing the usefulness of the Water Poverty Index by applying it to a special case: Can one be water poor with high levels of access? *Physics and Chemistry of the Earth*, Doi: 10.1016/j.pce.2008.03.005.

- Lawrence, P., Meigh, J. and Sullivan, C. (2003). *The Water Poverty Index: An international comparison*. Keele Economic Research Papers 2002/19, Keele University, UK.

- Molle, F. and Mollinga, P. (2003) Water Poverty Indicators: conceptual problems and policy issues. *Water Policy*, **5**(5), 529-544.

- Munda, G., Nijkamp,P. and Rietveld, P. (1994). Qualitative multicriteria evaluation for environmental management. *Ecological Economics*, **10**, 97-112.

- Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A. and Giovannini, E. (2005). *Handbook on Constructing Composite Indicators: Methodology and User Guide*. OECD Statistics Working Paper. OECD, Statistics Directorate, Paris.

- Odada, E.O., Olago, D.O., Bugenyi, F., Kulindwa, K.A.A., Karimumuryango, J., West, K., Ntiba, M., Wadinga, S., Aloo-Obudho, P. and Achola, P. (2003). Environmental assessment of the East African Rift Valley. *Aquatic Sciences*, **65**, 254–271

- Shah, T.; van Koppen, B. (2006).“Is India ripe for Integrated Resources Management? Fitting Water Policy to National Development Context. *Economic and Political Weekly*, **41**(31), 3413-3421.

- Singh, R.P., Nath, S., Prasad, S.C. and Nema, A.K. (2008). Selection of Suitable Aggregation Function for Estimation of Aggregate Pollution Index for River Ganges in India. *Journal of Environmental Engineering*, **126**(5), 451-455

- Sullivan, C. (2002). Calculating a Water Poverty Index. *World Development*, **30**(7), 1195-1210.

- Sullivan, C.A. and Meigh, J. (2007). Integration of the biophysical and social sciences using an indicator approach: Addressing water problems at different scales. *Water Resources Management*, **21**, 111-128.

- Sullivan, C.A., Meigh, J.R., Giacomello, A.M., Fediw, T., Lawrence, P., Samad, M., Mlote, S., Hutton, C., Allan, J.A., Schulze, R.E., Dlamini, D.J.M., Cosgrove, W., Delli Priscoli, J., Gleick, P., Smout, I., Cobbing, J., Calow, R., Hunt, C., Hussain, A., Acreman, M.C., King, J., Malomo, S., Tate, E.L., O’Regan, D., Milner, S. and Steyl, I. (2003). The Water Poverty Index: Development and application at the community scale. *Natural Resources Forum*, **27**, 189-199.

- Swamee, P.K. and Tyagi, A. (2000). Describing Water Quality with Aggregate Index. *Journal of Environmental Engineering*, **126**(5), 451-455

- UNICEF – Republic of Kenya (2006). *Water, schools and health Management Information System (MIS) for Turkana District*. Final Report. Nairobi: UNICEF.

- WHO/UNICEF (2000). *Global Water Supply and Sanitation Assessment Report 2000*. Joint Monitoring Programme for Water Supply and Sanitation, New York: UNICEF/WHO (available at: http://www.wssinfo.org).